Fariba Fahroo

Education

- A.B. in Physics and Applied Mathematics (UC Berkeley)
- M.A. in Mathematics (University of Wisconsin)
- Ph.D. in Applied Mathematics – Control and Optimization of Distributed Parameter Systems (Brown University)

Professional Experiences

- Professor in the Department of Applied Mathematics *at the Naval Postgraduate School*
- Program Manager at *the Air Force Office of Scientific Research (AFOSR)* – Computational Mathematics and Dynamics and Control
- Program Manager at *DARPA/DSO* (since March 2014) – Math Programs

Research Interests and Experience

Numerical Analysis, Nonlinear Optimization, Optimal Control, Stability Analysis of Partial Differential Equations

General Research Interests

- **New Paradigms for Modeling, Simulation and Design of Complex Systems**
  - Uncertainty in Models, Parameters, Operating Environments for Complex Systems
  - Curse of Dimensionality
  - Truly Multi-scale Models and Approaches
  - Interplay of “fast” vs “accurate” computations

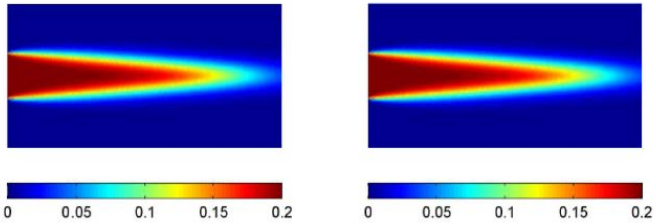
- **Analysis and Control of Complex Networks**
  - Distributed Control --- Local vs Global effects
  - Metrics for Controllability and “influence” of Networks based on Structure
  - Network Partitioning

- **Data Science --- Big Data Dynamics for Physical Systems**
  - Interplay of Models and Data
  - Role of Dynamics in Big Data
  - Stochasticity, Noise both in Models and Data
  - Structure, Geometry in Data

Big Ideas

Complexity and Uncertainty in Physical Systems

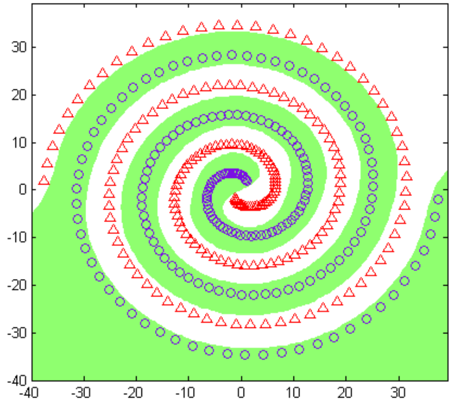
- How can we transition the simple forward model to uncertainty quantification and management in complex physical systems (vehicles, airfoil design, etc.)?
    - Dimensional reduction techniques to handle high dimensional uncertain parameter space
    - Methods for uncertainty in multiscale systems
    - Techniques for "model-form uncertainty"
    - Decision making and control in the presence of uncertain models
    - An emphasis on physically motivated methods and optimal solutions under limited computing constraints



For PDEs representing a jet flame in a combustor, a set of 3,383 coupled equations (solution, left) was reduced to 40 equations (solution, right) with a 50,000x speedup and relative error of $<10^{-4}$.

Fundamental Mathematics of Big Data and Algorithms

- How can we achieve fast machine learning and statistical inference at the terabyte scale?
    - Algorithms designed and optimized for large scale parallel implementations
    - Stochastic algorithms to break scaling ceilings
    - Higher risk approaches such as numerical algebraic geometry



Non-linear decision boundary drawn by a support vector machine separating red and black training points

Reza Ghanadan

Background:

- DARPA DSO PM since 2013
- B.S.: Double Degree Physics and Electrical Engineering
- M.S. and Ph.D.: Electrical Engineering
- MBA (Entrepreneurial Management)
- Previously with Boeing (Technical Fellow BR&T; Chief Network Engineer, BDS)
- BAE Systems (Engineering Fellow, Tech. Director: Network & Information Processing)
- Flarion Technologies (start-up, founding team, First 4G Wireless Data Networks)
- AT&T/Lucent Bell Laboratories – MTS (First DARPA Experience, Submarine sea-trial!)

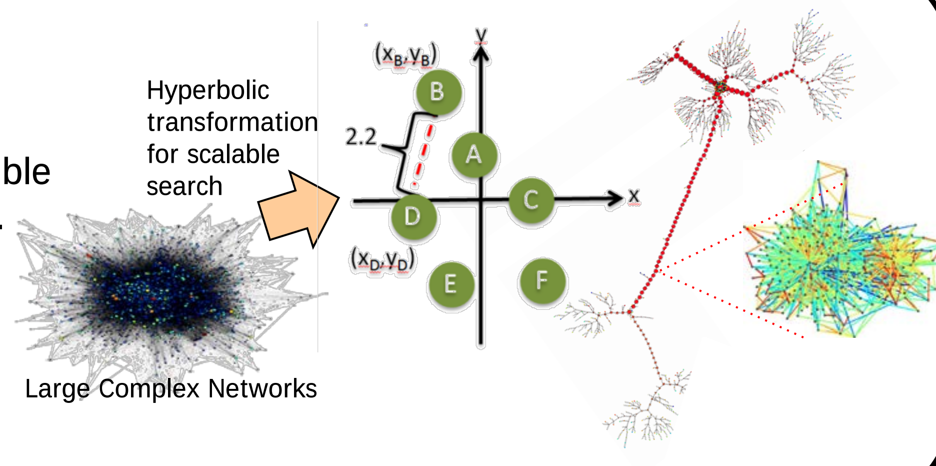
Areas of interest:

- Tools and methods for knowledge representation, integration, analysis in complex sciences and systems at scale (flexible but mathematically rigorous)
- Foundational information processing, network and communications technologies
- Applied and computational mathematics (methods and algorithms)
- Autonomy (perception, reasoning, learning, control, language, integrated systems)

What are you currently working on?

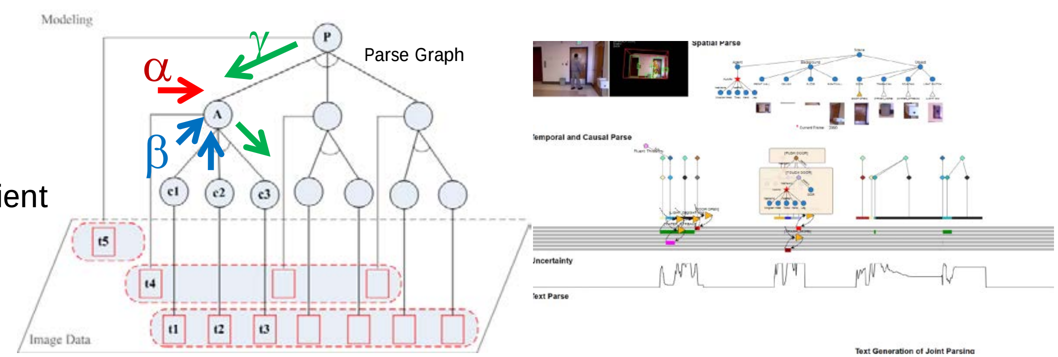
GRAPHS Program Vision: Develop rigorous mathematical models and scalable algorithms for the analysis of very large networks, find meaningful structures and patterns, and turn the results into flexible tools for modeling and analysis of complex use cases.

- Scalable and accurate inference tools with controlled precision
- Near real-time decision support for complex networks
- A toolbox of graph processing algorithms that scales to trillions of nodes



MSEE Program Vision: Develop a unified scene representation from multimodal inputs using flexible Bayesian models to achieve real time, actionable responses to semantic queries.

- Stochastic and context sensitive grammars for efficient representation of complex scenes
- Space-time-causal graphs
- Capture semantic and relational information
- Responsive to complex natural language queries

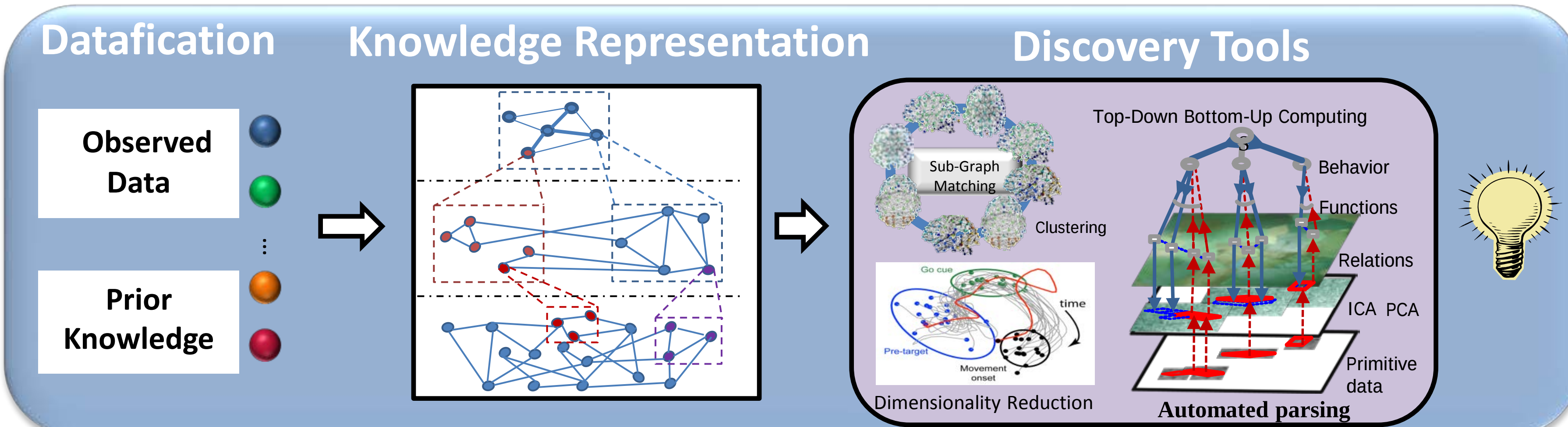


And-or-Graph data structure for real-time scene understanding

Big Ideas

- How to create a flexible unified representation for heterogeneous knowledge in complex systems?
- How to combine different scientific data (data ingestion)?
- Science Discovery Tools – How to incorporate available scientific knowledge along with uncertain observed data into models for hypothesis steering (unstructured analogies for Kalman filter)?
- What are efficient methods for learning and adapting knowledge at scale and in near-real-time?
- How to infer functions and properties from structures?

Complexity and Uncertainty in Systems



Examples

Neuroscience
Identify functional building blocks of learning, and demonstrate synthetic learning

Materials Science
Discovery and design of high performance thermoelectric materials that convert heat to electrical energy

Tyler McQuade

Education

UCI

B.S.
Double Major
Chemistry and Biology

Wisconsin

Ph.D.
Chemistry

MIT

Post Doctoral Fellow
Chemistry

Profession

FSU

Professor
Chemistry and
Biochemistry

Awards

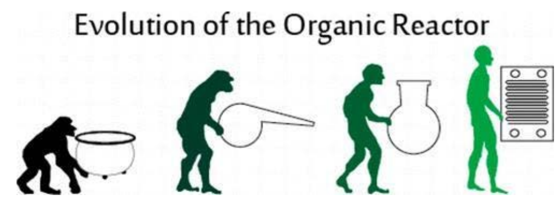
MIT Tech Rev.
Innovator Under 35

Beckman, Dreyfus, SM
Young Investigator

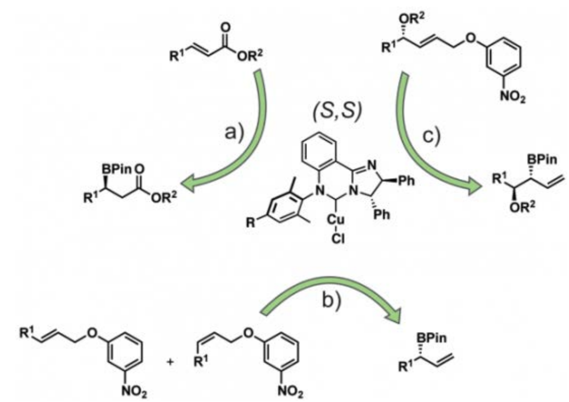
Etc...

Scholarship

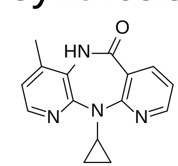
Flow Chemistry



Catalysis

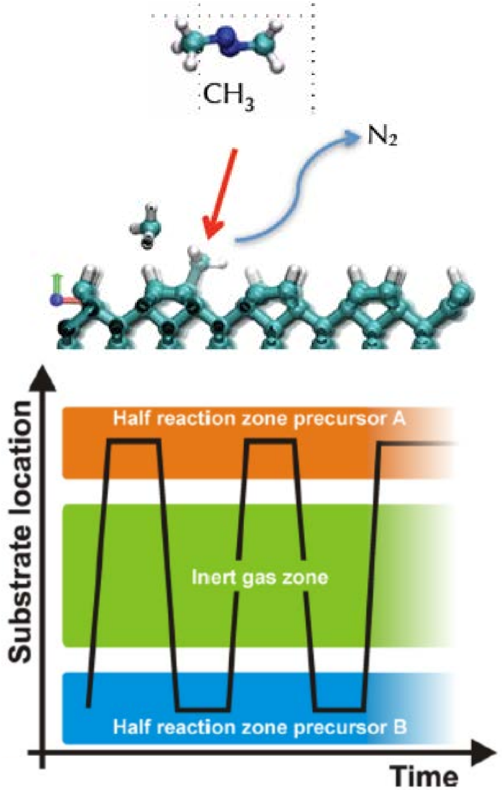


Synthesis



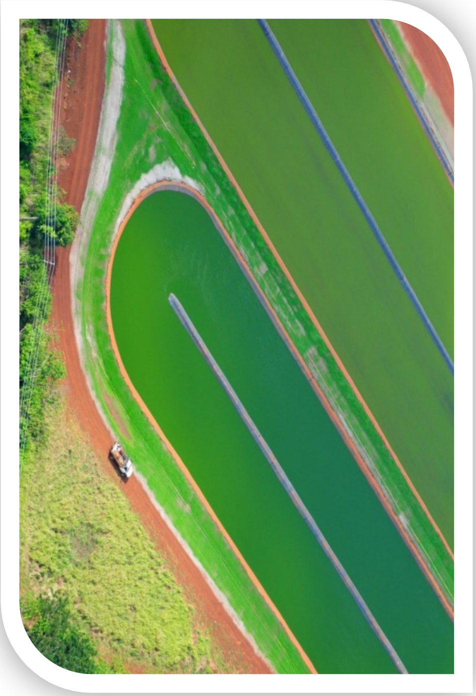
What are you currently working on?

Local Control of Materials Synthesis



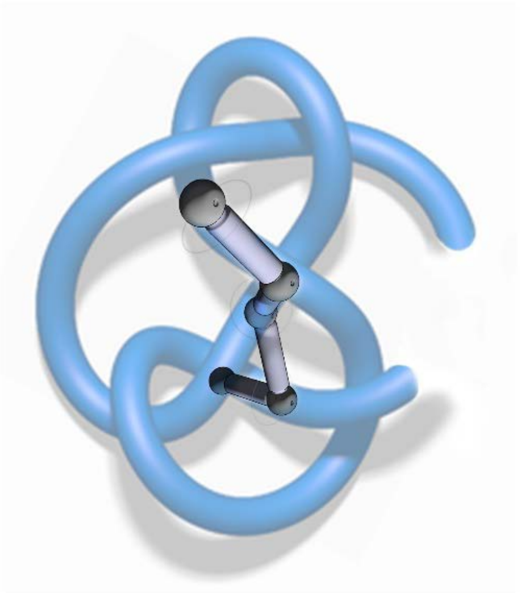
Accelerating New Coating Synthesis
Long-range QM Theory
High Flux Plasmas
Continuous Atomic Layer Deposition

Biofuels



Conclusion of DARPA/Biofuels
12-month Longitudinal Study
Establish Economic Feasibility

Folded Non-Natural Polymers with Biological Function



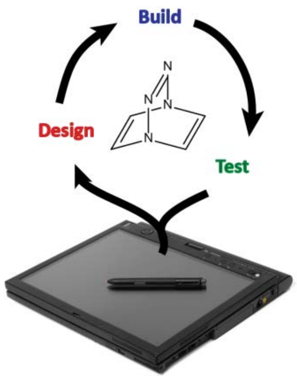
Effort to Kick Off Sept. 2014
Develop Methods to Prepare, Screen & Sequence Large Non-natural Polymer Libraries

Big Ideas?

Problems of Synthesis

Tools For Synthesis

Molecule synthesis is more art than science. What advances can place synthesis more firmly in the realm of science?



Functional Materials

Biological systems possess order across length scales that provide many value-added properties. How can molecular design and process tools be better united to create functional materials?

Up at Night

Non-lethal Motivation

Military power often focuses on lethality. When we engage in conflict with adversaries who might not be motivated by lethal action, what are our options? How can we expand our military toolbox to address this eventuality?

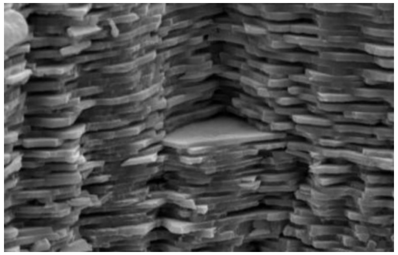
Natural Resources

Worldwide shortages could fuel conflicts in many parts of the globe. How can the United States help to limit shortages, maintain peace while preserving our high quality of life?

Concept Alignment

My Interests More Broadly

Basic science captivates but efforts at the interface of engineering and basics sciences is exciting as well.



Materials design across multiple length scales that perform function or can self-assemble into large structures are favored.

Novel sensing/detection – it's all about the molecules!

Mick Maher

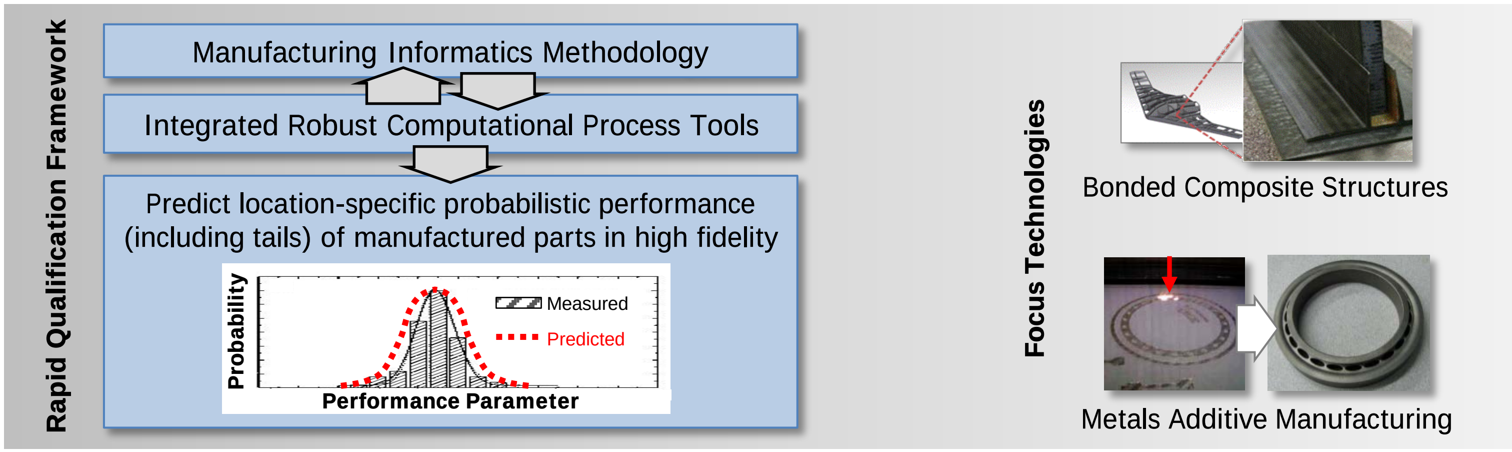
- **Industry – 20 Years**
  - Martin Marietta Baltimore
    - Production Support, Prototyping, Process R&D
  - AAI
    - Facilities Design, QE, Process Engineering, Business Development
  - DuPont/Fiberite/Cytec
    - Applications Engineering, Program Management, Plant Leadership, Business Development
  - Middle River Aircraft Systems
    - Master Planning, New Business Development

- **Government – 10 Years**
  - Army Research Laboratory
    - R&D Management of materials and manufacturing organizations
  - DARPA
    - Management of the Open Manufacturing and Advanced Structural Fibers Programs for DSO. Management of Manufacturable Gradient Refractive Index Optics Program for STO.

Existing Portfolio

Open Manufacturing

Predictable material properties and reduced qualification time through comprehensive capture, analysis, & control of manufacturing variability



Advanced Structural Fiber

Driving PAN-based composite fiber strength and stiffness performance to new levels

- Tensile strength: **5.75 GPa (non-circular fiber /100 filament tow)**
  IM7 – 5.3 GPa (6 K tow) and 5.67 GPa (12 K tow) – circular fiber
- Tensile modulus: **350 GPa (25% higher than IM7)**
- Thermal stability in air: **100 °C higher than IM7**

Manufacturable Gradient Refractive Index Optics (STO program)

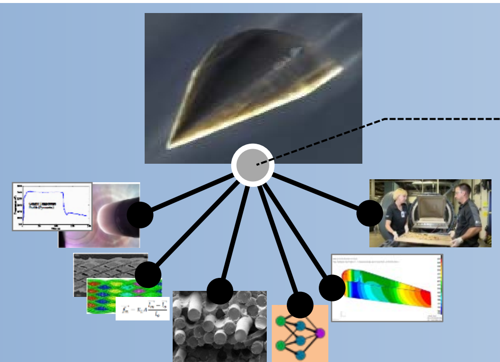
Areas of Interest

Areas

- New methodologies to accelerate materials development
- New high temperature materials
- Multifunctional materials
- Composite Materials

Cool Concepts

- Materials Development for Platforms



CONVERGENCE
- New concepts
  - o Design intent
  - o Material systems
  - o Manufacturability
- Analysis results

Decrease applied development cycle time for introducing and fielding a new material by 4X, and
Use hypersonic challenge problems to force material and design communities to integrate tools

- Achieving Aerospace Performance at Automotive Efficiency

Creating short fiber

- Small diameter fiber (<1 μm)
- High volume production (kg)
- Without chopping long fiber (creates defects)
- No detrimental surface effects (diameter > 20 nm)

Judah Goldwasser

- M.S. in synthetic chemistry
- Ph.D. in macromolecular chemistry

- NSWC Staff Scientist
  - Synthesis and characterization of explosive and propellant ingredients

- Office of Naval Technology
  - Deputy Technology Area Manager – Undersea Weapons

- Office of Naval Research
  - Program Officer – Energetic Materials and Undersea Warheads

- DARPA/DSO
  - Program Manager
    - Reactive Materials, Armor Materials, Structural Materials & Multifunctional Materials

Validation Test – Fluid/Structure Interactions

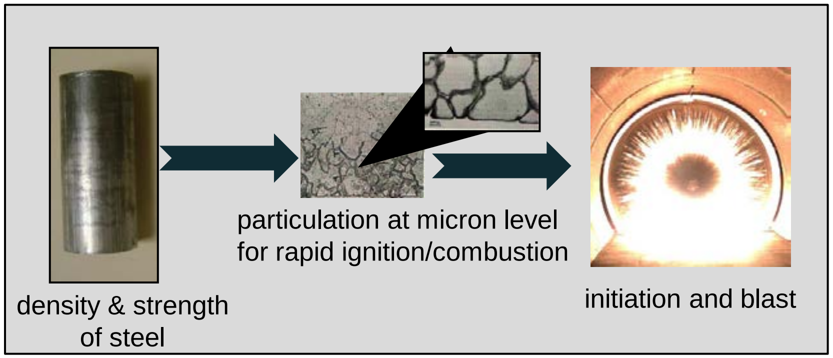
Overriding Theme of My Program Portfolio

- Dramatically increase performance by obviating compromises necessitated by conflicting requirements
  - Explosives – high power and insensitivity
  - Armor – resistant to projectiles but light
  - Thermal Management – load bearing but with high surface area
  - Acoustic/vibration damping – lossy but stiff
- Achieve fundamental understanding of controlling features/mechanisms
- Develop “multifunctional” materials with appropriate hierarchical features
  - Achieve and exploit synthesis methodologies across multiple length scales
- What keeps me up at night?
  - How to convert emerging fundamental discoveries into implementable technology for DoD applications
- Applicable DSO Topic Focus Areas:
  - Transformative Materials
  - Novel Sensing and Detection Enabled by New Science

Current Programs

RMS – Reactive Material Structure

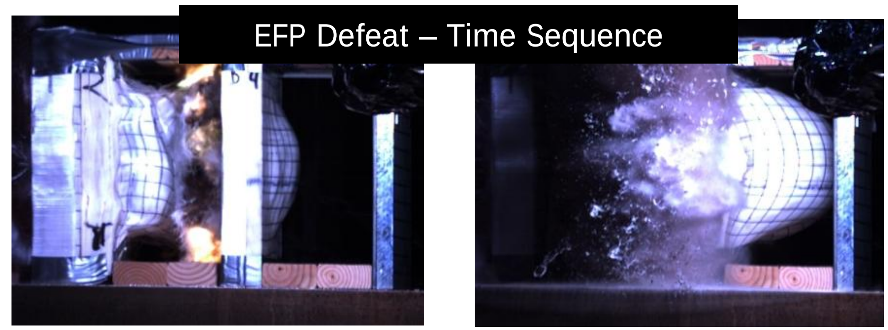
Develop and demonstrate materials with the strength of steel that can produce the blast output of an explosive



SPS – Soldier Protection Systems

Ballistic Armor & Underbody Blast Protection

Develop and demonstrate new armor concepts based on novel materials, new modeling capabilities and energy management approaches to more than double performance

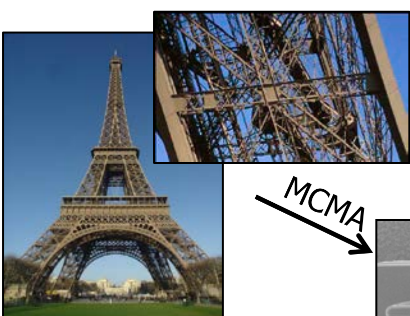


MCMA – Materials w/ Controlled Microstructural Architecture

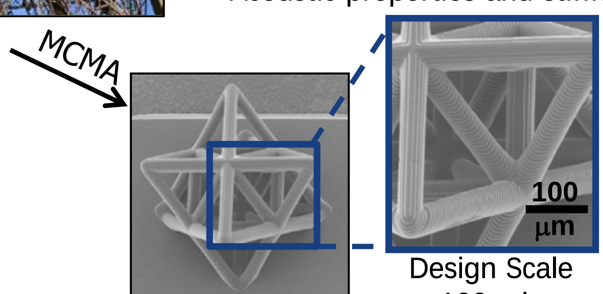
Apply structural engineering design to material microstructures

Decouple properties such as:

- Strength and density
- Coefficient of expansion & stiffness
- Fracture toughness and stiffness
- Thermal conductivity and density
- Acoustic properties and stiffness



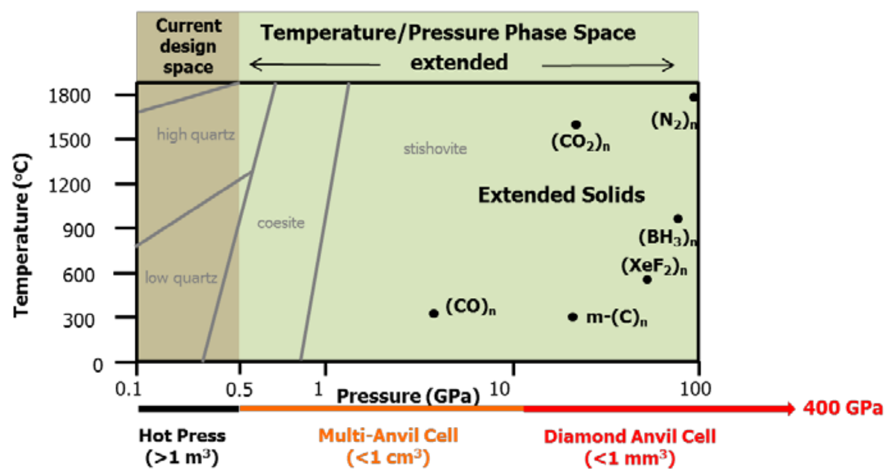
Design Scale
~meters



Design Scale
~100 microns

XSolids – Extended Solids

Access high pressure phases and unlock accessible synthetic chemical space to vast new materials and phases

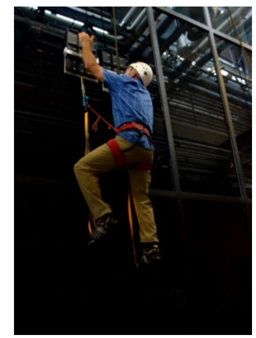


John Main

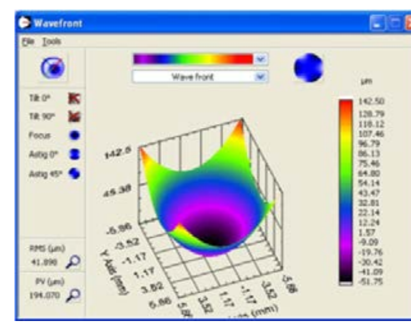
- DARPA DSO PM
  - New programs in the works!
- Chief Operating Officer of Intific Inc.
  - Software for simulation, visualization, and training
- Previously a DARPA DSO PM
  - Focused on robotics and systems for improved human performance (swimming, climbing, etc.)
- Founded Precision Systems and Instrumentation
  - Lab equipment for spinal cord injury research
- Assistant/Associate Professor of Mechanical Engineering at the University of Kentucky
  - Started and funded the Adaptive Structures Lab
- Also worked at U. Maine, NASA
- M.S. and Ph.D. in Mechanical Engineering
- B.S. in Physics and Mathematics

Microexpression Trainer

Powerswim



Z-Man



Wavefront Control

Portfolio Approach

- General approach is to focus on tools
  - Leveraging new science to provide better tools – New scientific discoveries underpin breakthrough products and capabilities. Rapid exploitation of emerging science to build tools is critical.
  - Creating tools to facilitate new science – The next step in scientific discovery frequently requires new investigative tools.
- Tools can be virtually anything – mechanical test machines, processing systems, visualization systems, software, whatever you need to get the job done.

Questions

- How do we leverage nanoscale material properties in real devices?
- Can we break the water purification/power linkage for small scale water purification?
- What science and technology should we be developing right now to support the projection of power for the next 50 years?

Gill Pratt

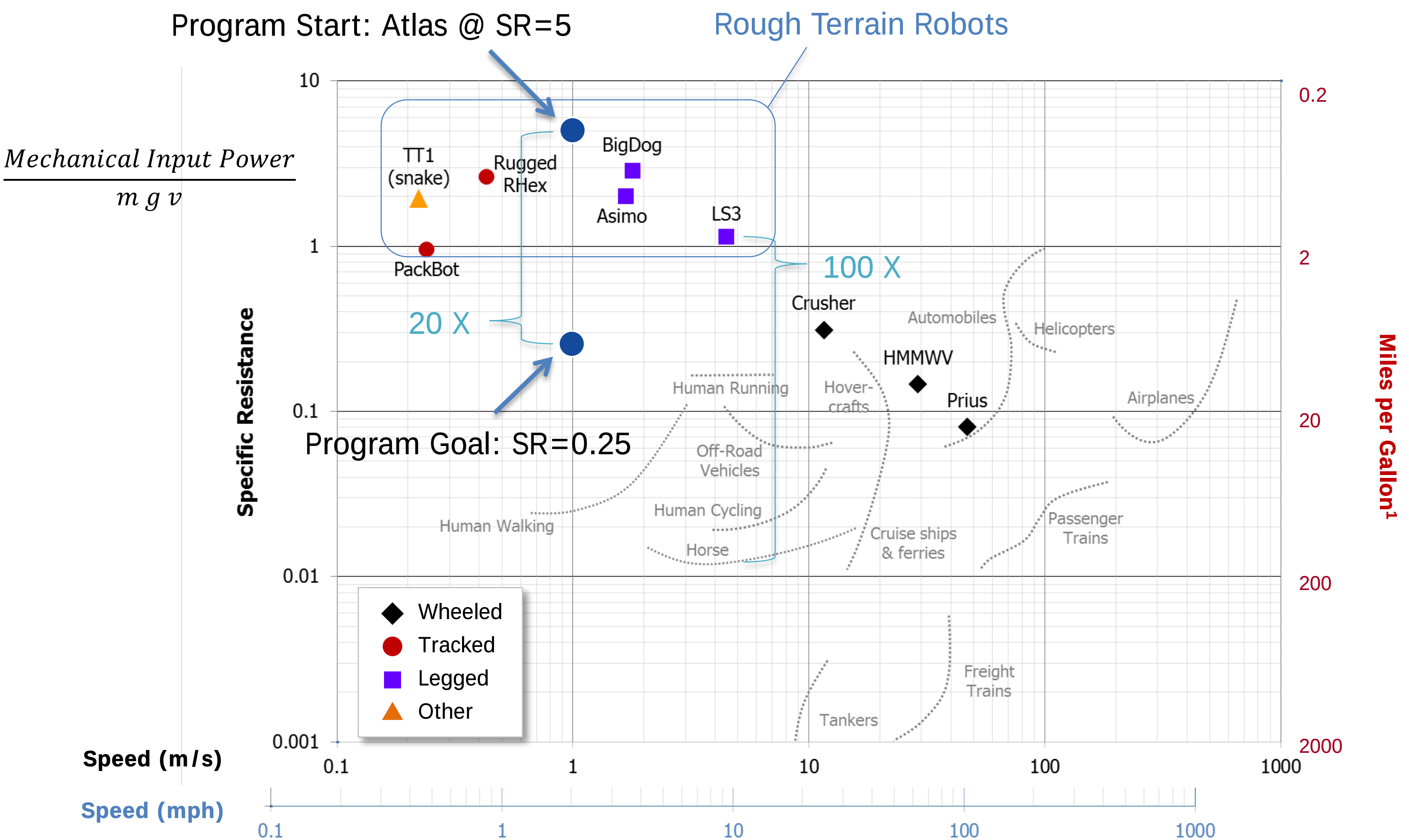
- Background
  - MIT EECS SB ‘83, SM, ‘87, Ph.D. (Neurophysiology) ’89, Post-Doc, Faculty
  - Directed MIT Leg Lab, Performer on TTO’s Tactical Mobile Robotics Program
  - Founding Faculty, Franklin W. Olin College
  - Previous DSO Programs include: Neovision2, NAV
  - Present DSO Programs include: ARM, M3, MENTOR2, SyNAPSE
  - Present TTO Program: DARPA Robotics Challenge

- Area of Interest – <u>Robotics Science</u> and Neuromorphic Systems

  - How can we create competent autonomy despite intermittent connection to cloud resources?

  - How can we lower the cost of complexity to manufacture efficient robots?

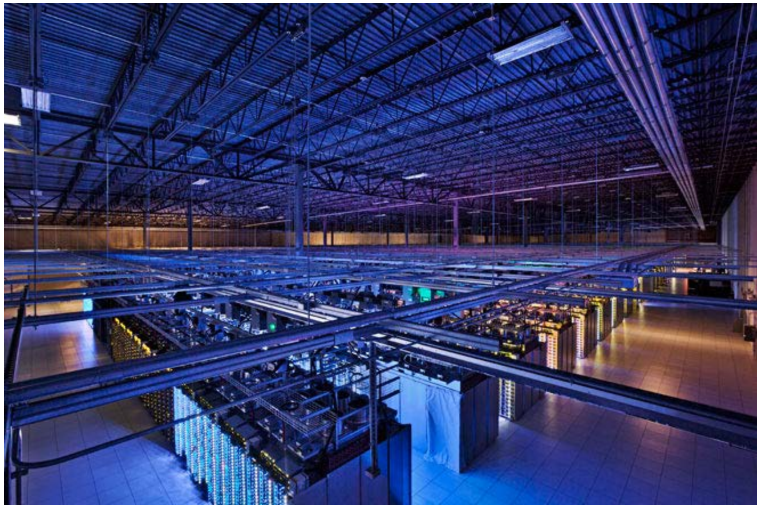
Specific Resistance in Natural and Engineered Systems



¹Miles per Gallon for a Toyota Camry (1045 kg) running on gasoline, using an energy conversion efficiency of 25%

Cloud Robotics + Robotics Beyond the Cloud

- World's data storage now measured in Zetabytes (10^21 Bytes)
  - By Comparison – Number of Synapses in Human Brain: ~ 10^14
  - About a trillion images have been uploaded.
- World's computing capacity approaching 1 Zeta OPS
  - Highest performance video games now do 80% of their computing on the cloud
- > 1 Mbit/s wireless connection to the internet becoming ubiquitous
- Batteries have low energy density (approx. 1/10 fossil fuels)
  - SWaP is at a premium in mobile devices.
- Hard part of robotics is between the ears (of the robot).
  - Many problems get easier with lots of data + processing
    - Example: Use of maps for autonomous driving
    - Example: Visual object perception
- **<u>Big Idea : Put the robot brain on the cloud</u>**
  - Side benefit – all robots learn from each robot's experience
- We still need to develop competency in:
  - Unstructured, austere environments
  - Intermittent Communications
  - Better-than-human performance
  - Low SWaP
  - Limited a-priori knowledge
  - Critical (human life) missions

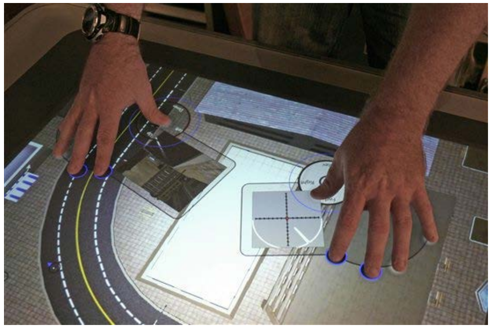


A server room in Council Bluffs, Iowa.
Photo: Google/Connie Zhou

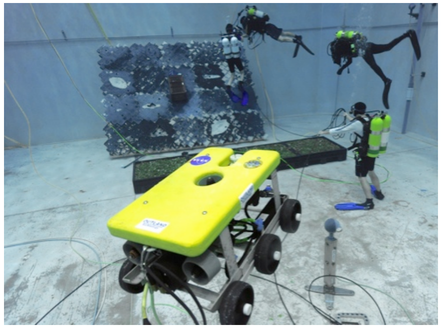
Mark Micire

- Computer Science
  - Human Computer Interaction
  - Autonomy / AI
  - Computer security
- Robotics
  - Ground
  - Space
  - Underwater
  - Air (learning)
- Search & Rescue / Fire Rescue
  - Technical Search Specialist with DHS/FEMA CATF3
  - Nationally certified firefighter
  - Training in HAZMAT, CBRNE, and WMD response

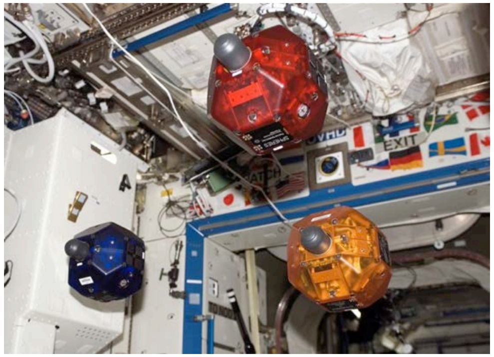
New program manager to DSO recently transferred from TTO



Photograph by University of Massachusetts Lowell



Photograph by NASA



Photograph by NASA

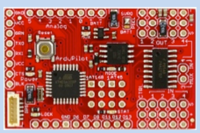
Photograph by Florence Ion for Ars Technica

Photograph by Mark Micire

Photograph by Florida Regional Task Force Three

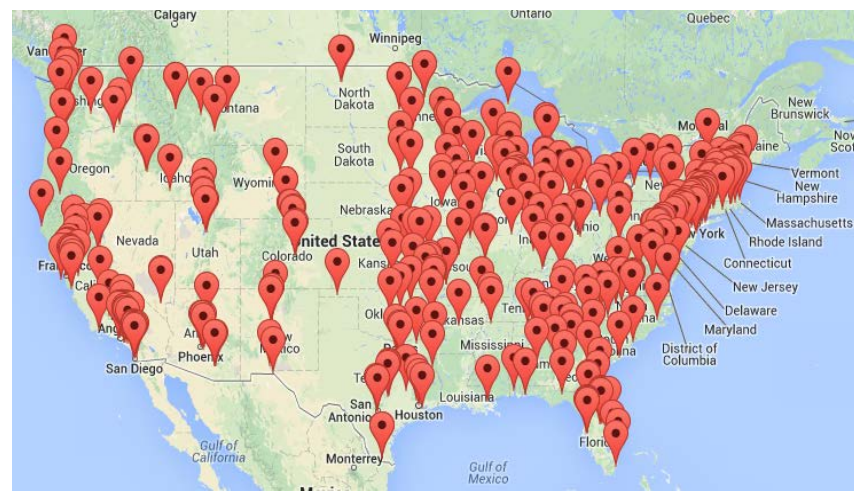
Research Interests

Create low-cost high-utility robots and their components by engaging an emerging community in research efforts that result in technology prototypes and proofs of concepts in months, at a fraction of the cost of traditional design processes.

Autopilot Software	Disposable Nano-UAVs	Man Machine Interfaces	
			…

- Reach a growing demographic of highly motivated, intelligent, and capable performers in the robotics hacker/maker community
- Tailor the contracting and programmatic formula for dual-use robotic technology development and non-traditional performers
- Encourage leveraging of COTS technology and rapid prototyping to dramatically drive down the cost of robotic systems
- Develop 12+ prototype systems and proofs of concept in months, at a fraction of the cost of traditional design processes

Source: http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-techshops-and-fablabs/



Source: http://www.adafruit.com/hacker_spaces/

Big Ideas

Supervised Autonomy

- Small and fast autonomous systems for covert reconnaissance
  - 10 rooms in 10 minutes fully autonomously
  - Minimal amount of autonomy succeed in camera and mapping mission
- Currently deployed models for robot autonomy are not scalable.
  - Currently 1:1 or greater human to robot ratios
  - We have been unable to “take the man out of unmanned systems.”
  - Not sustainable from a manpower, communications, or C2 perspective
- Applications for robot swarms are needed, but few solutions exist.
  - Platforms for small UAVs limited by power density and resupply capability
  - Autonomous behaviors need to mature and develop mission relevance
  - Heterogeneous teams with heterogeneous sensor suites need to be explored
- Very few examples of fully autonomous systems
  - Commercial investments in “cloud autonomy” must be understood and leveraged.
  - Adaptations and knowledge representation that can cope with disconnected environments must be explored (will not be explored by commercial investments).
- Human Robot Interaction and Man-Machine Interfaces
  - As autonomy increases, how do we create interfaces that maximize usability and learnability?
  - How do autonomous systems “explain” their state and decision space?

Doran Michels

- Former Army Infantry Officer
- Former FBI Special Agent
- Multiple combat tours in Iraq/Afghanistan
- Program thrusts: warfighter empowerment, organizational adaptation

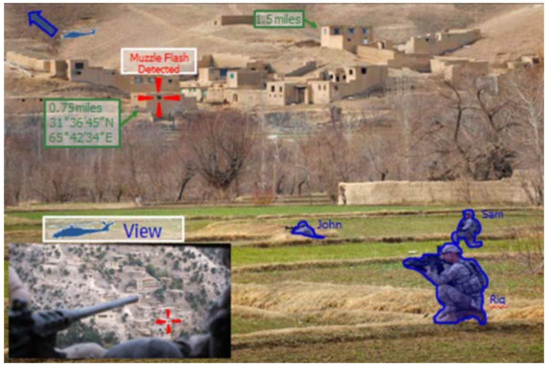
Current Programs

- I2O Transformative Apps Program (TransApps):

  Today's consumer has access to an unprecedented volume of real-time information, and smartphones have changed many aspects of our lives. In contrast, modern warfighters have few tools to access, manage and share information on the battlefield. The TransApps Program addresses this gap by exploring a new paradigm for tactical mobility.

- DSO Soldier Centric Imaging with Computational Cameras (SCENICC):

  Tomorrow's warfighters must perceive their environment in unprecedented ways, and act quickly and appropriately to win. The goal of the SCENICC program is to advance our knowledge of several key technologies in optics, interfaces and novel sensors to deliver a more complete and intuitive level of situational understanding.



- DSO Tactical Advanced Power (TAP) / Stalker XE:

  The TAP Program is focused on rethinking tactical power. By leveraging earlier DARPA investments in Solid Oxide Fuel Cell (SOFC) microtubules, DARPA quadrupled the endurance of a fielded small-unit UAV platform. We are now pursuing similar advancements for tactical ground power applications.

Areas of Interest

- Applications of the modernized OODA-loop (Observe, Orient, Decide, Act)
- The poor-man's “Red Team”: consumer-grade adversaries
- New materials for warfighter weapon systems

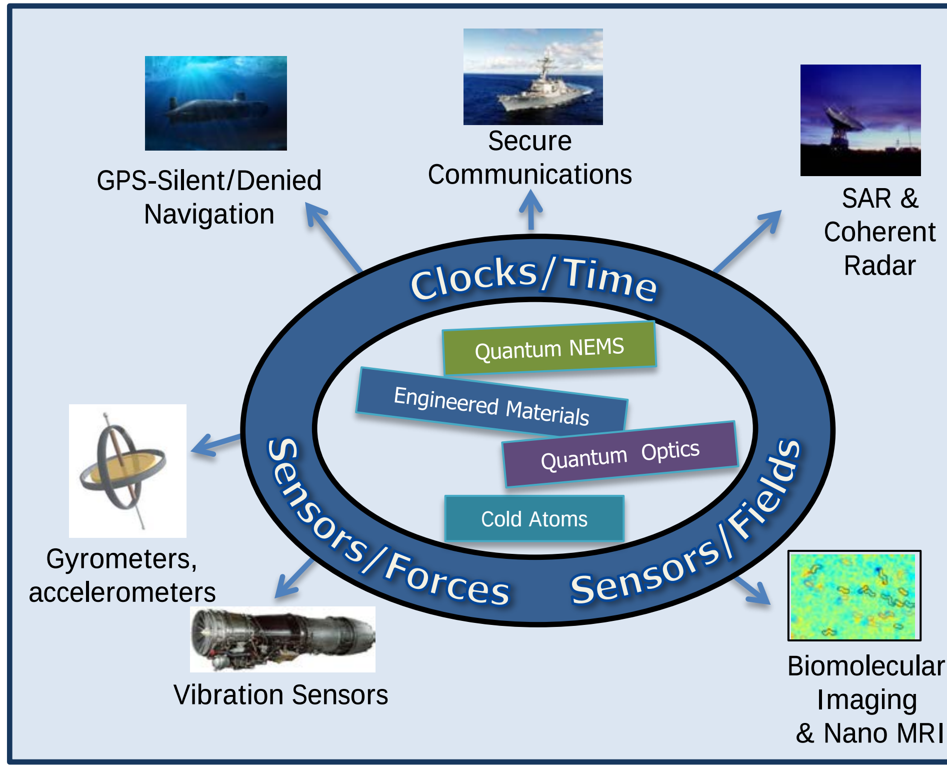
Jim Gimlett

- Distant past
  - B.S. Applied Physics, Caltech; Ph.D. Physics, Caltech
  - Fundamental physics (studies of time-reversal invariance), experimental nuclear & particle physics
- Occupation trajectory – Caltech, Swiss Institute for Nuclear Research, Bellcore, Tektronix, Network Elements Inc., Alternative Power Generation of Canada
  - Basic physics research (neutrino physics), applied R&D and product development (fiber optic communications and video networking), helped found two startup companies (high speed communications engines, alternative energy)
- Interests
  - Sensors, transducers and actuators of all kinds based upon new physics, optics, nanofabrication and novel multifunctional materials
  - Multifunctional materials and materials modeling
  - Complex adaptive self organizing systems (engineered, physical, biological)
  - New science applied to energy production, conversion, storage
- Miscellaneous
  - Musician, songwriter, playwright

Current Programs

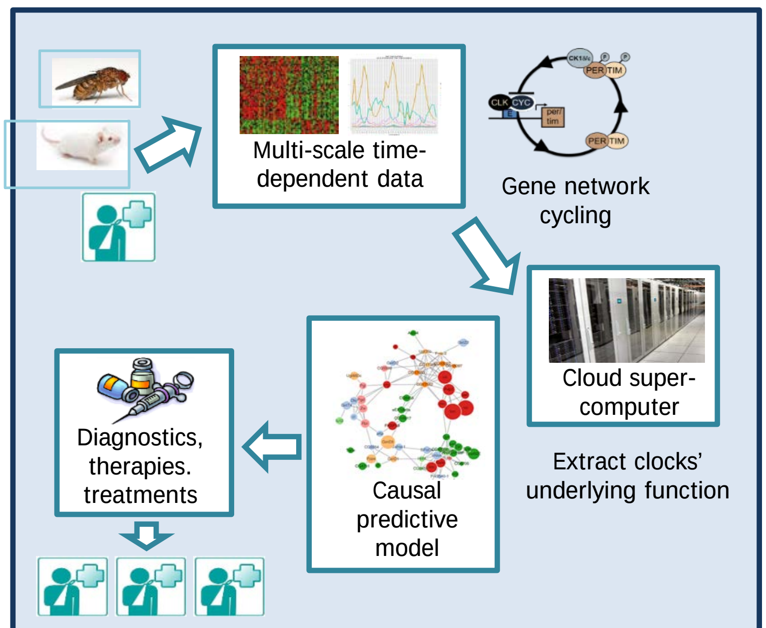
QuASAR

- Next generation sensing and measurement based on quantum optics, quantum atomic physics, and nanoscale opto-electromechanical materials



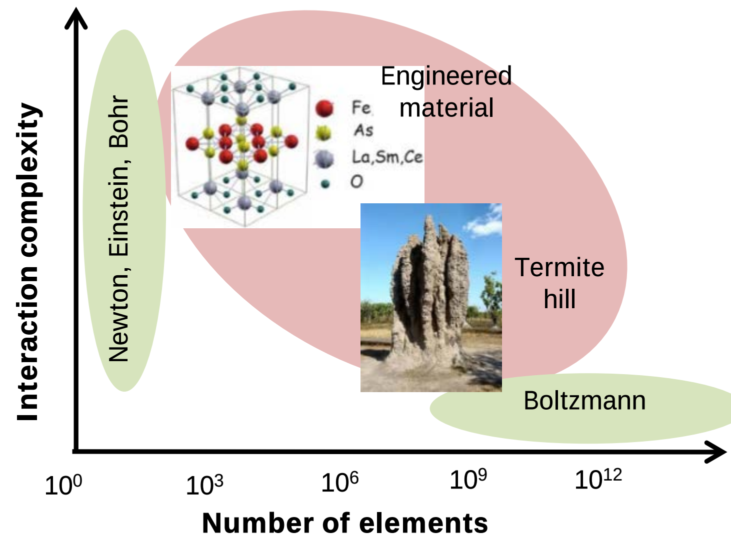
Biochronicity

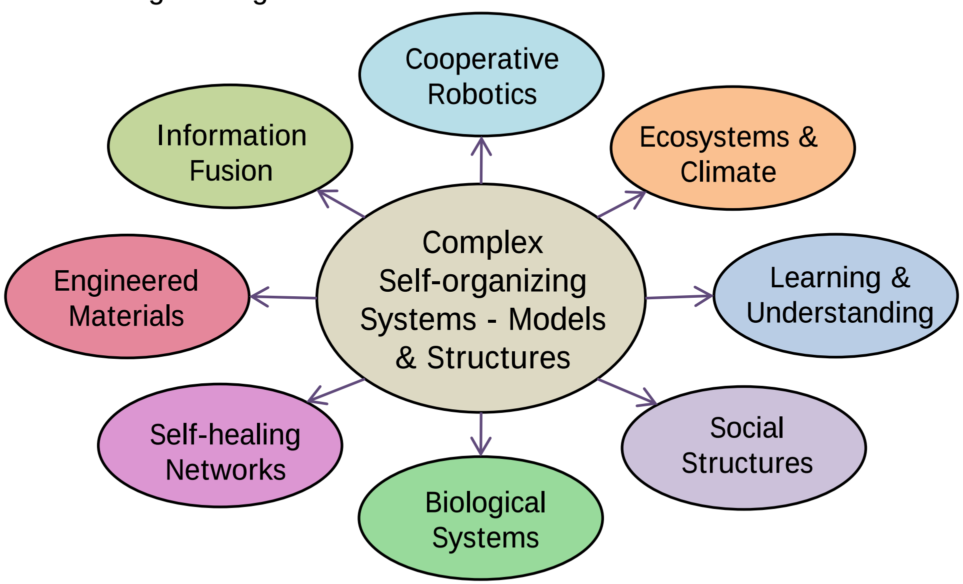
- Multi-scale dynamic modeling of complex biological systems
- Predictive chrono-diagnostics and chrono-therapy



New and transformative physics across scale:

- **Physics** – quantum, photonics, nuclear, atomic, condensed matter
- **Multifunctional materials** – e.g. photonic/phonic/electronic, multiferroic, thermoelectric, nanoscale optical MEMs
- **Devices** – sensors, transducers, actuators, logic and storage devices
- **Systems** – clocks, measurement systems, sensor networks
- **Complex Hierarchical Systems**
  - Self organization & regularities are pervasive.
  - Principles and predictive models have been elusive.
  - Few tools for predicting macro behavior from micro rules and predicting micro interactions from macro behavior
  - Agent based models have not scaled well or bridged to system engineering.





Questions:

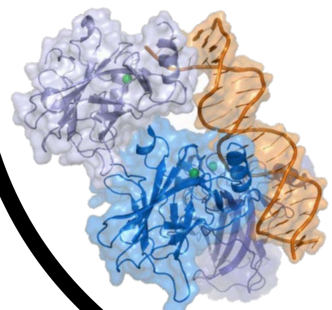
- Are we missing something fundamental, e.g. better information representations, mid-layer abstractions, nonlinear dynamics, general principles or inferable heuristics?
- Or are these problems fundamentally hard and irreducible?
- If the latter, can we still extract something useful, e.g. parametric dependencies, bounds on behavior, anticipate chaotic regimes, traverse scales?
- Are we asking the right questions?

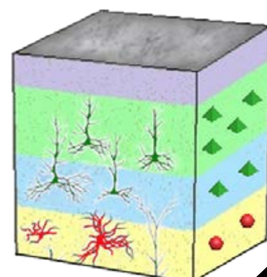
Areas of Interest → Intersection of Multiple Fields!

Physics / Chemistry

Biology

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$
$$H(t)\,|\,\psi(t)\rangle = i\hbar \frac{d}{dt}\,|\,\psi(t)\rangle$$





Engineering

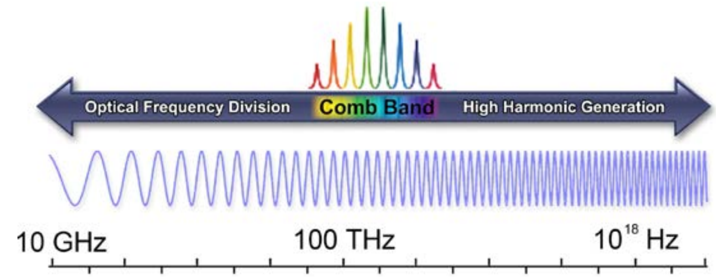
Computation / Signal Processing

Background: Professor at Northwestern University (quantum optics, classical communications, quantum biology, imaging & sensing)

Current Programs: Optics, Quantum, Bio

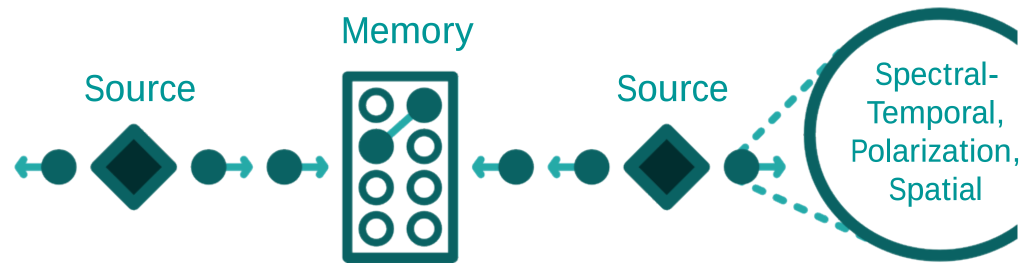
Program in Ultrafast Laser Science and Engineering (PULSE)

- GOAL: Enable efficient use of the entire electromagnetic spectrum
- APPROACH: (1) Engineer waves in the optical domain; (2) Convert to any spectral region – DC to X-rays; (3) Reduce size, weight, and power



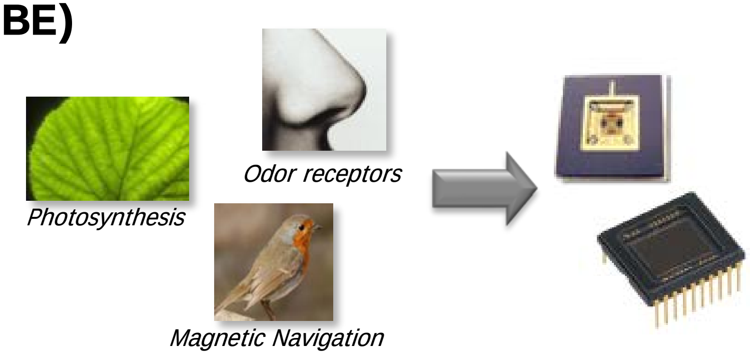
Quantum Communications (QUINESS, InPho)

- GOAL: High-rate quantum communications
- APPROACH: (1) Next-generation quantum repeaters; (2) High-dimensional encodings; (3) Exploiting classical theory



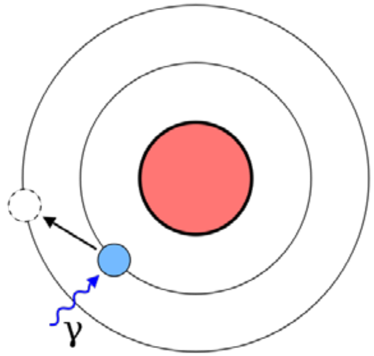
Quantum Effects in Biological Environments (QuBE)

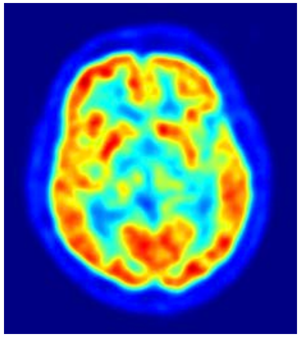
- GOAL: Enable biomimetic sensors
- APPROACH: (1) Demonstrate that nature uses manifestly quantum effects in biological systems; (2) Create synthetic systems which exploit those quantum effects

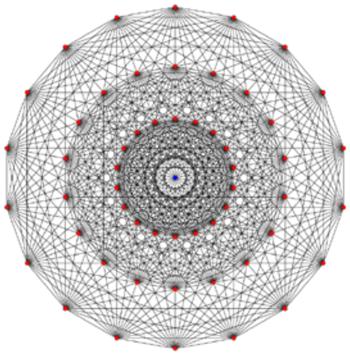


Looking Forward: Fundamental Questions

- What are the fundamental limits of quantum detection and measurement (e.g., for photo-detection)?
- How do photonic fields transition to excitonic/matter fields? Can understanding this process lead to better devices for quantum manipulation and sensing?
- How can we exploit extreme quantum and nonlinear effects for enhanced sensing and communication?
- Are biological circuits (e.g., cortical neuronal circuits) as difficult to model as quantum circuits?
- Can either biological or quantum circuits be understood (and synthesized) in a new way?
- Does back-action in biological systems limit (or enhance!) our ability to understand them?
- Are there efficient algorithms, usable on real technology, for imaging through complex, highly scattering media?



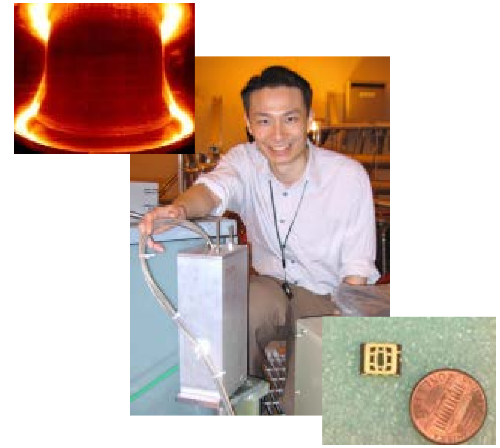




Vincent Tang

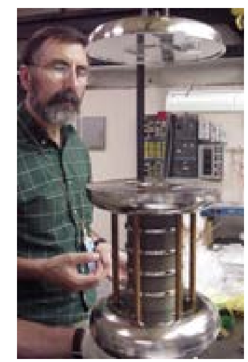
Interests: Nuclear science, applications, and security

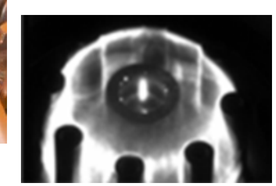
- Counter-WMD, radiation detection and sources, energy, quantitative risk analysis, applied physics



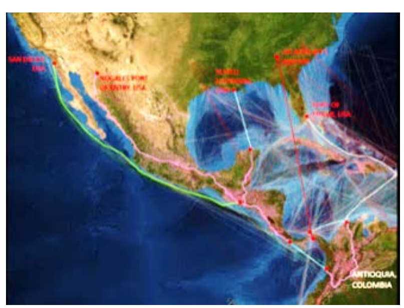
Background:

- UC Berkeley: B.S., Nuclear and Chemical Engineering; MIT: M.S. Nuclear Engineering
- MIT: Ph.D. Applied Plasma Physics
  - Developed first-of-a kind neutral particle detector for heated ions in fusion reactor regime; resolved key physics
- LLNL: Staff Physicist/PI
  - Developed and led multiple efforts involving novel compact accelerators and pulsed plasma radiation sources for National Security applications





What are you currently working on?



SIGMA

Demonstrate continuous and cost-effective state-scale, network pervasive nuclear and radiological WMT detection capability

- Increase detector efficiency and resolution using low cost, scalable techniques to achieve 10x lower cost and significantly increased spectroscopic gammas and neutron sensitivity
- Construct and optimize adaptive wide-area sensor networks with data fusion to maximize detection capability
- Develop CONOPs leveraging existing infrastructure and perform at-scale demonstrations

What keeps you up at night?

DEFENSE SCIENCES OFFICE

How do we tap, develop, and use wisely the immense potential of the nucleus?

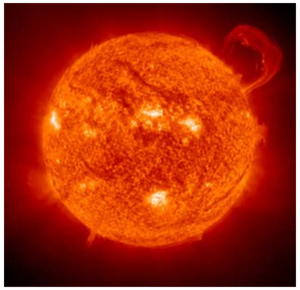
- Probes: How do we make neutron imaging as ubiquitous as x-ray imaging so that we can know an object without touching it?
  - Can we develop practical multi-MV, man-portable accelerators for directional neutron sources through the convergence of new materials, automated predictive design, and additive manufacturing?
    (Topic: Novel Sensing and Detection)

- Energy: How do we make controlled fusion a reality?
  - Can we develop and use faster predictive capabilities for complex plasma systems to enable compact fusion? Are there better approaches to particle modeling?
    (Topics: Fundamental Limits of Physical Phenomena; Complexity and Uncertainty in Systems)

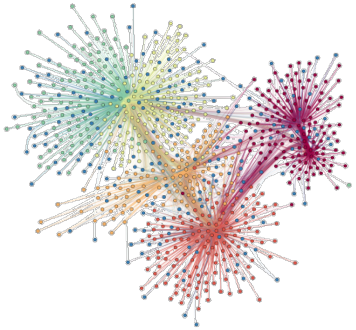
- Security: How do we understand and mitigate the risks of increasing asymmetry in the WMD space?
  - Can we quantify the risks of catastrophic attacks in the near-to-mid future by developing new predictive modeling capabilities for complex social systems? How do we massively scale agent based and network models?
    (Topics: Complexity and Uncertainty in Systems)

Are there novel hardware or analog computing techniques that are commonly enabling for particle and agent based modeling?

E. H. Lehmann et al, Archaeometry, vol. 52, 2010



(NASA website)



T. Crnovrsanin et al.